Nanoscale Studies of Ferroelectric Phenomena in Perovskite Thin Films

O. Auciello and D.J. Kim, Argonne National Laboratory, Materials Science Division
V. Nagarajan and R. Ramesh, University of Maryland, Materials and Nuclear Engineering Department

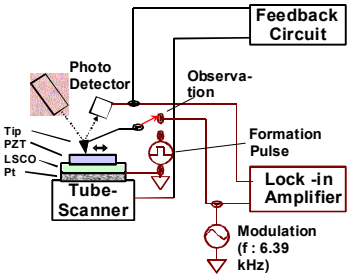
MOTIVATION

- Studies of ferroeleectric phenomena in oxide perovskite thin films at the nanoscale are critical to explore the limit of ferroelectricity in these materials and understand the fundamental ferroelectric phenomena at the nanoscale
- Fundamental and applied science of oxide perovskite ferroelectric thin films provide the basis for the development of a new gneration of multifunctional micro and nanodevices such as the revolutionary non-volatile ferroelectric random access memories (FeRAMs) currently in the market in the form of low density FeRAMS in "smart cards" and the up- coming high density FeRAMs for posed to replacve DRAMs and Flash memories.

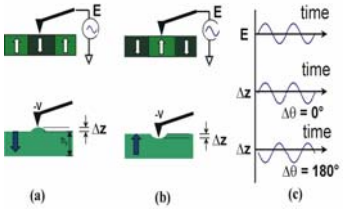
MAJOR ACCOMPLISHMENTS

- We developed top-down approaches for the fabrication of nanocapacitors to study ferroelecrtic phenomena at the nanoscale
- We used nanocapacitors fabricated via the top-down approach to study ferroelectric domain phenommena at the nanoscale and demonstrated for the first time that 90° domain switch when the the ferroelectric thin film is patterned in nanostructured capacitors that eliminate lateral geometrical constrains prevalent in blank films.
- WE obtained valuable information that may provide evidence for the limit of ferroelectricity in nanostructured perovskite thin films, which in turn will make a major impact in the design of the future high-density FeRAMs.

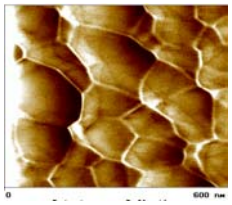
RESULTS



Schematic of AFM piezoresponse imaging system for nanoscale studies of ferroelectric domains

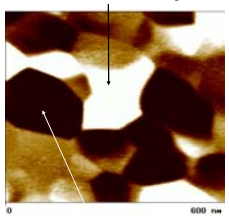


polarization domains created in ferroelectric film by electric field between top (AFM tip) and bottom electrode



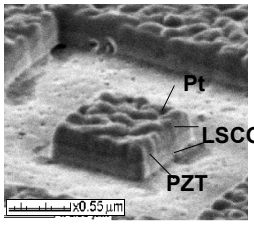
AFM topography image

Polarization up

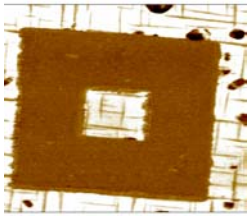


Polarization down

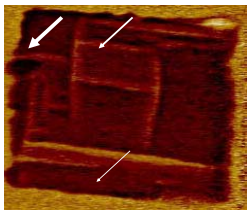
AFM piezo-image

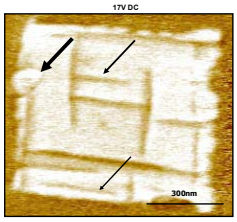


PZT nanocapacitor fabricated via FIB etching

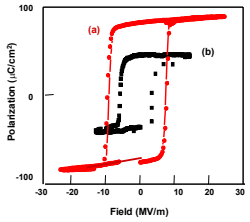


PZT nanocapacitor polarized up showing 90° domains (lines)

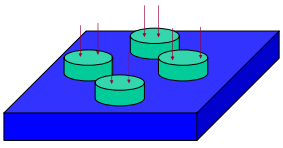




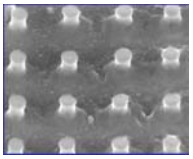
First show of 90° domain switching in PZT nanocapacitors (lines move)



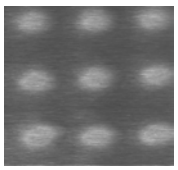
Polarization loops for PZT nanocapacitor (a) and for constrained capacitor (b)



E-beam fab of PZT nanocapacitor



PZT nano-capacitor array via FIB



Piezoresponse image of PZT nanocapacitor array

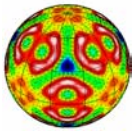
IMPACT

The fundamental and applied science of ferroelectric phenomena at the nanoscale wil impact the high-density FeRAMs and other nanodevics technologies

FUTURE DIRECTIONS

Preliminary experiments performed in our lab shows the way to functionalization of ferroelectric surfaces that open a new field of research on micro and nano-biointerfaces and devices

Dynamics of Ferroelastic Domains in Ferroelectric Thin Films", by V. Nagarayan, A. Roytburd, A. Stanishevsky, S. Prasertchoung, T. Zhao, L. Chen, J. Mengailis, O. Auciello, and R. Ramesh, Nature-Materials 2 (2003) 43.



BES - DOE

This work was supported by the U. S. Department of Energy, Basic Energy Sciences, under contract W-31-109-ENG-38. Work with the FIB was carried out at the Center for Microanalysis and Materials, University of Illinois, which is partly funded by the U. S. DOE under grant DEFG02-91-ER45439.

MSD - ANL

ARGONNE NATIONAL LABORATORY · UNIVERSITY OF CHICAGO